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Standard Reference Materials:

Calibration of NIST Standard Reference Material 3201 for 0.5 Inch (12.65 mm) Serial Serpentine Magnetic Tape Cartridge

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22 track, 6667 ftpi (262 ftpmm) and
48 track, 10000 ftpi (394 ftpmm)

by

Mark P. Williamson, Natalie E. Willman, and Dana S. Grubb

Abstract

This publication describes the test system design and operation for the calibration of the NIST Standard Reference Material (SRM) 3201 Secondary Standard Reference tape for 0.5 inch (12.65 mm) 22 and 48 track serial serpentine magnetic tape cartridges. The importance of producing a Standard Reference Material for this magnetic tape cartridge is to promote the ability to interchange data both within and among various computer installations. Reliable interchange requires that the media be designed and manufactured on the basis of a comparison to a known and accepted standard reference media.

Key words: digital magnetic tape, Master Standard Reference tape, overwrite, peak shift, Secondary Standard Reference, signal amplitude, Standard Reference Material

1. INTRODUCTION

Standard Reference Material (SRM) 3201 is produced in support of American National Standard (ANSI) X3.197-199X for unrecorded media and X3.181-1990 for recorded media.

Magnetic tape standards are essential to the development of a community of vendors with interchangeable products. With several vendors building drives and media to voluntary standards, users can be assured of both competitive development of the products and a reasonable product lifetime. The latter is essential for archival storage, since archival data is useless without the drives and subsystems capable of reading it.

NIST's role in the development of magnetic tape standards goes far beyond active participation in Technical Committee X3B5, Digital Magnetic Tape, and other regional and international standards development committees. Several of the properties essential to the interchange of the new high density magnetic tapes cannot be directly measured from the media. The output signal amplitude, the typical write current, frequency rolloff, the ability to overwrite old data, and peak shift all require dynamic measurements relative to a master tape. All of the new and proposed magnetic tape standards specify several parameters requiring such dynamic measurements.

Vendors and users of several important digital magnetic tape technologies depend upon NIST as the world source for Secondary Standard Reference tapes calibrated against Master Standard Reference tapes held in repository at NIST. In addition to Standard Reference Materials (SRMs) for open reel 0.5 inch (12.65 mm) computer tape, two 0.25 inch (6.30 mm) tape cartridges and a cassette tape, NIST is completing work on three SRMs for newer high density tape cartridges. (The Physikalisch-Technische Bundesanstalt in Germany provides a similar service for flexible disks cartridges.)

Earlier SRMs developed by NIST include SRM 3200 and SRM 6250 (open reel tape), SRM 1600 (1600 ftpi cassettes), and SRM 3216 (3200 ftpi cartridges). These SRMs are produced on a system which is entirely manual in operation. The system uses a ramp generator for the write current and direct plotting on an analog recorder.

SRM 3217 (6400 and 10,000 ftpi cartridges) is produced on a second system that is partially computer-controlled and has a digital plotter.

SRM 3201 is the first SRM produced on a new generation of computer-controlled systems developed at NIST. All instruments in the test system are commercially available. The software and the peak-to-peak detector, as well as several specialized digital circuits, were developed by NIST. This new system uses a computer-controlled current source to provide the write current. Other computer-controlled instruments are used to measure the write current and the peak-to-peak read voltage, and to provide the write frequency. Tape drive motion is controlled via an RS-232 interface and a TD70-B controller. In addition, digital output lines from the write current instrument are used to reset various circuits. Files for each tape tested are stored by the computer on magnetic media.

The 0.5 inch (12.65 mm) serial serpentine magnetic tape cartridge has 48 tracks recorded when used in high density drives and a physical recording density of 10,000 flux transitions per inch (ftpi) (394 ftpmm). When used in low

density drives, 22 tracks are recorded at a physical recording density of 6,667 ftpi (262 ftpmm).

The SRM consists of a digital magnetic tape in its cartridge and documentation of the tape's performance relative to the Master Standard Reference tape's performance, on the following tests:

- saturation: to make a plot of the average signal amplitude as a function of the write current.
- overwrite: to determine the ratio of the average signal amplitude of the residual of the 1F recording frequency (half the maximum frequency), after being overwritten by the 2F recording frequency (maximum frequency), to the average signal amplitude of the original 1F recording frequency.
- resolution: to determine the ratio of the average signal amplitude at the 2F (maximum) physical recording density to that at 1F (half the maximum) physical recording density.
- peak shift: to measure the time displacement of adjacent read back signal peaks from the corresponding written timing.

The following sections explain the testing methodology, the system hardware and the system software of SRM 3201.

Note: Manufacturer's names and model numbers are cited solely to identify the hardware, software, and equipment used and do not imply a recommendation.

2. TESTING METHODOLOGY

2.1 Self-Correcting Calibration System

SRM 3201 Secondary Standard Reference tapes are calibrated using an optional self-correcting calibration system. This scheme is fully documented in an article cited in reference 1.

In this self-correcting scheme, there is a Master Standard Reference tape, from which several working tapes are calibrated against. The data is stored in table form on magnetic disk and a magnetic disk backup medium.

The Secondary Standard Reference tapes will be calibrated at some later date, and subsequent batches calibrated over a period of years. At the time of the calibration of the secondary tapes, one of the working tapes is run and a correction factor table is determined, which is defined as the differences between the working tape data when it was first run, and the current working tape data. If significant differences are found, this "correction factor" table may then be added to the data gained when the Secondary Standard Reference tapes are run. This will correct the system's gain adjustments which may have drifted since the Master Standard Reference tape was selected.

2.2 Saturation Test

The saturation test is defined as a plot of the average signal amplitude as a function of the write current. The tape is written with an incrementing current, and the average signal amplitude produced by each current setting is read from the tape and stored in a table. These values are then plotted with average signal amplitude on the y axis and write current on the x axis.

Certain values are derived from the saturation test. For all tapes, the following values are calculated:

Peak amplitude (Ap) - The maximum average signal amplitude.

Peak current (Ip) - The write current corresponding to the peak amplitude.

Typical amplitude (At) - 95 percent of the peak amplitude (Ap).

Typical current (It) - The write current which produced the typical amplitude (At).

When a Master Standard Reference tape is chosen and a saturation test is performed on it, the following data are calculated:

Standard reference current (Ir) - the typical current of the Master Standard Reference tape.

Standard measurement current (Im) - 1.5 times the standard reference current (Ir) as defined in the standard for the unrecorded media.

Standard reference amplitude	-	the average signal amplitude from the Master Standard Reference tape when it is recorded with the standard measurement current (Im).

When a Secondary Standard Reference tape is calibrated, the following data are collected for both physical recording densities:

- Standard reference current (Master Tape)
- Standard measurement current (Master Tape)
- Typical current (Test Tape)
- Ratio of It to Ir
- Ratio of the test tape's average signal amplitude at the standard measurement current to the standard reference amplitude.

Figure 1 shows an SRM 3201 saturation (SAT) curve produced by this system. The x axis is write current in milliamperes and the y axis is the read output voltage in amplitude units. (Amplitude units are normalized to 40 units for the Master Standard Reference tape.)

2.3 Overwrite Test

Overwrite is defined as the ratio of the average signal amplitude of the residual of the 1F (half the maximum) recording frequency, after being overwritten by the 2F (maximum) recording frequency, to the average signal amplitude of the original 1F recording frequency.

A tape is recorded at the 1F physical recording density at the standard measurement current (Im). The average signal amplitude of the 1F pattern is read from the tape. The tape is then recorded at the 2F physical recording density at the standard measurement current. The average signal amplitude of the 1F pattern is read from the tape.

The ratio of the overwritten 1F pattern's average signal amplitude and the original 1F pattern's average signal amplitude is then calculated.

2.4 Resolution Test

Resolution is defined as the ratio of the average signal amplitude at the 2F (maximum) physical recording density to that at the 1F (half the maximum) physical recording density.

A tape is recorded at the 1F physical recording density at the standard measurement current, and the average signal amplitude is recorded.

The tape is AC bulk erased and recorded at the 2F physical recording density at the standard measurement current. The average signal amplitude is recorded.

The ratio of the average signal amplitude at the 2F physical recording density to the average signal amplitude at the 1F physical recording density is then calculated.

2.5 Peak Shift Test

Peak shift is defined as the time displacement of adjacent readback signal peaks from the corresponding written data.

The tape is written with a pattern of 110110110 using the standard measurement current for the selected physical recording density.

The time between adjacent peaks in the ONE-ONE interval is denoted at T1. The time between the last ONE in the ONE-ONE interval to the last ONE in the following ONE-ONE interval is denoted as T0.

The time interval measurement is defined in the unrecorded media standard as the average of 250 recorded patterns taken at a sampling rate of 96 x the 2F frequency.

Peak shift is calculated using the following formula:

$$\text{peak shift} = \frac{3T1-T0}{2T0} \times 100 \text{ percent.}$$

3. INTRODUCTION TO SYSTEM HARDWARE

Manufacturer's names and model numbers are cited solely to identify the equipment used and do not imply a recommendation. Such identification is essential, since the system software must be written using the control/status codes and data formats specified for the particular equipment. Alternative equipment may be used, but some modification of the system software will be necessary. As the instruments are set up by the software, those interested in the instruments' settings should consult the software listings for the instrument drivers. (Source code is available on magnetic media from NIST.)

Figure 2 shows the system interconnection. It is essential that the 50 ohm terminators be used as shown. (The

terminators are available from Hewlett-Packard.) The output of the current source is connected using a triax to coax converter (available from Keithley). The connections to DVM1 (HP 3456A) are floating measurements; the coax shields on the two inputs are connected together and to the instrument's ground input. The 1 MΩ input of the HP3585A is used.

3.1 Commercially Available Instruments

The computer is an IBM PC AT with a 30 Mbyte hard disk, two floppy disks drives, math co-processor, and the PC DOS 3.2 operating system. A computer that is software compatible and has similar or better performance could be used instead. An RS-232 output is used to control the TK70-B tester.

The interface to the instruments is via the IEEE-488 interface board. The board selected is the National Instruments GPIB-PC2A (IEEE-488) interface board. This GPIB was purchased with its PC DOS handler and Turbo C language interface object code. (The manufacturer has interface object code available for several other compilers.)

A Hewlett-Packard 3325A frequency synthesizer/function generator is used for the write frequency and a Hewlett-Packard 5334A universal counter is used to check the write frequency. However, use of the counter is not essential, since it is only used as a check on the calibration of the generator. The synthesizer provides a square wave pattern via a gate circuit in the peak shift ring counter unit to the tape drive for all measurements except peak shift. For peak shift, the square wave is used as an input to the peak shift ring counter for generating the proper peak shift test pattern.

A Stanford Research SR620 time interval counter is used to make the peak shift measurements.

A Keithley 224/2243 programmable current source with triax to BNC adapter is used to provide the write current. This instrument has a relatively lengthy 23 ms. switching/ settling delay for the small current increments used in making saturation tables. (This delay is compensated by a software delay in the dcs1wr() function.) Range changes are avoided by setting the range in the PA (parameters) file high enough for the largest write current to be used. This instrument also has a 4-bit digital output that is used for software generated resets to the system. Bits 0, 1, and 2 (Pins 7, 8, and 9) are used to reset the peak shift ring counter, the TK70-B controller, and the E13 write flip-flop, respectively.

A Hewlett-Packard 3456A digital multimeter is used to measure the write current. The guarded input circuit is important when making floating measurements of the write circuit. (If

when making floating measurements of the write circuit. (If an alternative instrument is considered, its suitability for such measurements should be closely examined.) The write current measurement is not essential, since it is used only as a proof that the write current was close to that intended.

A NIST-designed peak-to-peak detector circuit (described elsewhere in this document) is used to measure the read amplifier output amplitude. A Hewlett-Packard 3457A digital multimeter is used to measure the dc output level of the peak-to-peak detector. (Alternatively, an HP3456A could have been used instead with its driver software instead of the HP3457A.)

A Hewlett-Packard HP3585A spectrum analyzer is used to make the overwrite measurements. A Hewlett-Packard HP3586C selective level meter would have provided more precise measurements, except that its maximum bandwidth is less than required by the speed variations of the tape drive. Consequently, the signal would drift in and out of band and provide unacceptable results. A Hewlett-Packard 7550A graphics plotter with IEEE-488 bus interface is used to plot the SRM saturation curve charts.

3.2 Tester Assembly

Figure 3 shows the Digital Equipment Corporation (Digital) tester assembly provided by Digital. It is a clear plastic box with mountings for various components, connectors on the rear and a clear plastic dust cover.

The assembly contains a modified Digital TK70 tape drive, a TD70-B (modified TD50-B) controller and a NIST-designed peak shift measurement circuit. These components are described subsequently.

The connector assignments at the rear of the Digital tester assembly are:

Coaxial connectors:

- Port 1 - Output signal (E31-17) to peak-to-peak detector
- Port 2 - Output signal (E31-16) to peak-to-peak detector
- Port 3 - Peak shift signal to SR620
- Port 4 - Write frequency from peak shift ring counter unit
- Port 5 - Current source from Keithley 224
- Port 6 - Write current measurement high to HP3456A
- Port 7 - Write current measurement low to HP3456A

RS-232 cable from IBM PC AT to TD70-B controller.

Twisted pair wires from Keithley 224 digital output pins:

Pin 8 (Bit 1) of Keithley 224 to TD70-B controller reset

Pit 9 (Bit 2) of Keithley 224 to TK70 drive reset

3.3 TK70 Tape Drive Modifications

The TK70 tape drive must be modified to permit control and measurement of the write current, control of the write frequency, resetting of the write frequency flip-flop, crippling of the automatic gain control, and access to the read signals. All connections except the reset are made using coaxial cable. Tape drive motion is controlled by the TD70-B controller unit. Logical track 02 (physical track 26) near the middle of the tape is used for all tests as specified in ANSI X3.197-199X and X3.181-1990.

The write current source circuitry is modified by cutting the connection to the tape drive's current source at R47 and inserting a connection to the external current source (Keithley 224/2243) at the emitter of E30 (see fig. 4). The coax shield is grounded at both ends. A 1000 ohm 2 watt resistor is connected in series with the current source and mounted in the drive near E30, which tends to improve the time constant for the circuit by reducing the effect of circuit inductance. The write pulse wave shape is very close to that of the unaltered drive.

The write pulse current value is checked by measuring the voltage across a precision 10 ohm resistor inserted in the write head center tap circuit. This is done by inserting the resistor in the output of E25 pin 8. The voltage drop across the resistor is measured with the HP3456A digital multimeter. The frequency of the tape drive is controlled by connecting the output of the HP3325A frequency synthesizer (via the gate circuit in the peak shift ring counter to the input of the write frequency flip-flop in the drive. This is done by breaking the connection at E13 pin 3 and attaching the frequency input at that point. Since the flip-flop divides the frequency in half, the synthesizer must be set to double the frequency (see fig. 4).

The write frequency flip-flop is externally reset by cutting the connection to E13 pin 1 and attaching a twisted pair to Bit 2 of the Keithley 224 current source. This allows the software to reset the flip-flop as necessary.

The AGC (automatic gain control) is crippled by cutting the connections from resistors R106 and R107 to E6 pin 9, and by

cutting the pin 2 side of R84 and the pin 13 output of E19 (see fig. 5).

The read signal for the saturation curve, resolution and overwrite measurements is obtained using the outputs from E31 pins 17 and 16. The read signal for the peak shift measurements is obtained using the output from E31 pin 10 (see fig. 5).

3.4 TD70-B Controller

The TD70-B is a Digital TD50-B controller (tester) with a modified PROM (programmable read-only memory) and an NIST-installed connection for external resetting. The modified PROM is available from Digital at a reasonable cost. (The Digital representative on Technical Committee X3B5 would be the contact person.) The reset connection is made by cutting the connection to E10 pin 9 of the Controller and attaching a coaxial cable to that point.

3.5 Peak Shift Ring Counter

Figure 6 shows the NIST-designed peak shift ring counter. This circuit provides the peak shift write pattern which is modified by the flip-flop in the tape drive to produce a "110110" pattern on tape. The software prompts the operator to put the switch in the bypass position for all tests except peak shift. In the case of peak shift, the switch is used to write the normal all 1's pattern during the calibrate cycle and the peak shift pattern thereafter. The output of the ring counter uses a 50 ohm line driver. It is therefore necessary to hard wire a 50 ohm termination on the write frequency input (Port 4) of the Digital tester assembly. The Counter is reset by Bit 0 from the Keithley 224.

3.6 Peak Shift Output Circuit

Figure 7 shows the NIST-designed peak shift output circuit. This circuit is needed to convert the narrow peak shift pulses from the tape drive into full width pulses for the SR620 time interval counter. (It is adapted from the circuit specified in ANSI X3.137-1988 for 90 mm floppy disk.) The circuit has a 50 ohm line driver as its output. The SR620 is set to 50 ohm termination by the software.

3.7 Peak-to-Peak Detector

Figures 8 and 9 show the NIST-designed peak-to-peak detector circuit. The peak-to-peak detector is used for the read signal because a peak-to-peak reading is specified by the standard. (A base-to-peak detector has potential baseline shift problems and an rms detector would be valid only if the

read signal was a pure sinusoid with no harmonics.) With the integrator on the output of the detector, it will measure over the minimum length of tape specified by the standard. The peak-to-peak detector provides a low-noise dc output for measurement by the digital voltmeter.

The input to this circuit is a differential signal from the TK70 drive that has some odd harmonics content. The output of the first stage is used to drive two base-to-peak detectors of opposite polarity. The two base-to-peak values are summed in the output stage.

The standard requires that the measurements be averaged over at least one inch (25.4 mm) of tape. This is done by the integrator on the output. The integrator is designed for about three time constants for the one inch of tape at the 100 ips (inches per second) of the drive. This has been found empirically to provide about the ideal amount of integration.

The detector's response is linear within 1 percent from 350 to 1350 mV and from 250 kHz to 500 Hz, the ranges of interest for this SRM. (The detector is also linear within 2 percent from 100 kHz to 2 MHz.) The circuit design relies on the use of a particular type of operational amplifier (Comlinear CLC-400), Polypropylene or similar specification capacitors and other selected components. While the operational amplifiers are quite stable, the offsets should be adjusted prior to calibrating tapes.

The detector also has an output from the first stage that is used for converting the differential read signal into a single-ended output for the HP3585A spectrum analyzer.

3.8 Offset Adjustment of Peak-to-Peak Detector

The peak-to-peak detector is quite stable, but the offsets should be periodically readjusted. Following is a list of steps to adjust the detector:

1) Turn the power on and let the detector warm up for at least 1 hour.
2) Ground the two differential inputs to the detector using BNC connectors with shorting wires.
3) Using an oscilloscope with a high gain preamplifier capable of at least 10 mV/division sensitivity, adjust the differential amplifier. Place the scope probe on the output of the amplifier (U1 pin 6) and adjust R7 for ground level on the oscilloscope.
4) Repeat step three for the linear halfwave rectifiers. Place the probe on U2 pin 6 and adjust R15, then place the probe on U3 pin 6 and adjust

R21. As U2 and U3 are subject to noise, adjust the outputs for an average level of zero.

5) Use a high input impedance voltmeter capable of reading to 1 mV to adjust the offset of the inverting summing amplifier. Place the probe on U4 pin 6 and adjust R23 for an average reading of zero.

Each amplifier will drift approximately ±5 mV for output levels in the 500 mV and higher range, this means an error of less than 1 percent even when the detector has not been used for a while.

3.9 Alternatives to the Use of a Peak-to-Peak Detector

Some drive and media manufacturers use a spectrum analyzer, a selective level meter, or an rms reading digital voltmeter for their testing. A spectrum analyzer does not measure over the length of tape specified by the standards. Also, a spectrum analyzer has a lot of noise even at the minimum bandwidth permitted by tape speed variations. Hence, the precision is too limited. A selective level meter is excellent when used with a tape drive having precise speed control (e.g., a Honeywell 96 instrumentation drive) and when no significant harmonics are present. However, it has too narrow a bandwidth for the tape speed variations found in production tape drives. Also, there are significant harmonics present with this media. Since the amount of harmonic content varies with write current, this would introduce an unnecessary error in the measurements. Some digital voltmeters read rms. However, the conversion from rms to peak-to-peak is known only if there is no significant harmonic content. Also, most digital voltmeters do not have good precision at these frequencies.

3.10 Head Degaussing

It is essential to periodically degauss the write/read head in the TK70 drive. Carefully remove the head and degauss it. Replace the head and test the system using a control tape to ensure that the head has been properly mounted.

4. INTRODUCTION TO SYSTEM SOFTWARE

The software is public domain, and source code is available on floppy disks to interested parties.

The system software is menu-driven with computer control of all aspects of the tape testing. The operator is asked to key in answers to necessary questions, such as: the type of tape to be tested and the type of test to be performed.

4.1 Development Environment

The program is written in C language, which allows low-level control of the hardware. In addition, C can be compiled to efficient object code, is portable with little modification between widely varying computers (e.g., IBM PC AT and VAX 11/780), and is designed for writing structured programs. Software maintenance for a program written in C is much easier than that of a program written in BASIC.

The software was written using an IBM PC AT computer with DOS 3.2. Early development was begun on a VAX 11/780 under VMS and transferred to an IBM PC XT and then to an IBM PC AT.

Since the instruments needed for the system are all designed with very different commands, responses and formats, the source code is unique for each instrument. (Even very similar instruments from the same manufacturer, such as the HP3456A and HP3457A digital multimeters, are designed with totally different commands and responses.) Therefore, the substitution of other instruments will necessitate a re-write of the drivers.

The software should run properly on most IBM-compatible personal computers having a hard disk and DOS Version 3.2 or later. The graphics functions used for displaying the saturation curves are specific to EGA monitors, and would require slight modification if another monitor is used. Computer speed should approximate that of an IBM PC AT or better.

The program is compiled using Borland Turbo C Version 1.5, although there are several other C compilers available that would probably be satisfactory. However, the IEEE-488 interface board used in the system must come with object code that works with the compiler. The compiler selected should make use of the math co-processor chip and should produce relatively fast object code.

The system program should compile properly with most compilers, except for the graphics which use library functions specific to Turbo C. Also, the input byte and output byte functions are not specified in exactly the same way by all compilers, so modification of how these functions are specified would be needed. Segment addressing is not used, since both the program and the data use less than 64 kbytes.

4.2 Software Structure

The system software consists of two executable files, sat-3201.exe for the saturation test, and orp-3201.exe for the overwrite, resolution, and peak shift tests. These

linked together.

Sat-3201.exe Modules	Orp-3201.exe Modules
- svar.h	- svar.h
- ovar.h	- ovar.h
- smain.c	- omain.c
- spec.c	- ospec.c
- sgen.c	- ogen.c
- s488.c	- 0488.c
- s-3201.c	- 0-3201.c
- slog.c	- olog.c
- tcibs.obj	- tcibs.obj
- graphics.lib	- graphics.lib

The smain.c and omain.c modules contain the main() function and the highest level functions. The spec.c and ospec.c modules contain the next lower level of functions which are specialized to the test being performed. The sgen.c and ogen.c modules contain all of the general purpose functions, except those using the IEEE-488 bus. The s488.c and o488.c modules contain all the IEEE-488 bus functions used to control the various instruments. The s-3201.c and o-3201.c modules contain all of the functions that are specific to SRM 3201. The slog.c and olog.c modules contain routines for logging test data. The tcibs.obj module is provided by National Instruments, the manufacturer of the IEEE-488 bus interface board. The graphics library is provided with Turbo C.

The #include files specified by the software modules, svar.h and ovar.h, are provided with the software listing. Two others, stdio.h and math.h, are supplied with the compiler. The file svar.h and ovar.h contain C structures with variables used by several functions.

4.3 #Define Statements

There are several #define statements that are essential to proper functioning of the system. Those affected by the choice of computer model or compiler used are described here.

The screen is cleared using a print function with the #define statement "CLEARS." CLEARS is set to "\033[2J" for an IBM PC AT. This declaration appears in several modules.
The function "delay" is used in several places to force specific timing delays needed. The function is passed the desired delay in milliseconds. Since this function uses software to create the specified delay, the value for its parameter DLY_CT must be set for the particular computer and compiler used. If a different computer or compiler is used, it is <u>absolutely essential</u> that the value of DLY_CT be

checked. DLY_CT appears at the beginning of the sgen.c and ogen.c modules.

Several other #define statements are needed for the particular instruments selected. Different instruments would, in some cases, need different #define values.

4.4 System Files

The system uses several files that are stored on disk: the parameters file, the current source files, and the correction factors file. Each tape type has its own set of files with each set identified by a single character for the tape type. SRM 3201 uses the letter "d" for low density and the letter "e" for high density.

4.4.1 Parameters File

Each tape type has a "parameters" file to specify such parameters as srm number, tape speed, etc. The parameter files for SRM 3201 are "dpa" and "epa."

Each parameter (pa) file contains the following parameter values expressed as ASCII character strings:

- tape type
- SRM number
- length of tape in feet
- tape speed in inches per second
- tape density in flux transitions per inch
- flux transitions per sample
- read while write or read after write
- track number used
- the minimum write current in mA
- the maximum write current in mA
- increment of write current in mA
- array size
- the standard reference current factor (.95 for this SRM)
- the standard measurement current factor (1.5)
- whether the current source or the voltage source is used (current source is used for this SRM)
- voltage drop in write head circuit (needed only for voltage source)
- resistance in series with the write driver circuit that is used to change the time constant by reducing the effect of circuit inductance (called "wdr")
- resistance from write head center tap connection that is used for measuring the write current (called "DVM1res")
- range of the current source (or voltage source) used (set high enough to avoid range changes during operation)

- amount of tape in feet to skip before testing
- the initial delay (dly1) prior to the first write current
- the incremental delay (dly2) for each write current increment
- the peak noise factor This value of this parameter is determined empirically for eliminating the noise spikes at the peak amplitude
- the amplitude unit scale factor for primary and master originals (determined empirically to approximately normalize data for the plotter).

The dly1 and dly2 values cited above are determined by the response of the current/voltage source and the time constant of the integrator on the output of the peak-to-peak detector.

The array size is the result of the difference between the maximum and minimum write current, divided by the write current increment. (Thus, the array size is redundant information, but included to permit a software check that the operator is specifying what is really desired.) Array size is limited to 400 due to the memory addressing limitations of the 80286 microprocessor used in the IBM PC AT class computers. (If more than 16 address bits were available, larger arrays would be permissible.)

The actual dpa and epa files are:

<u>dpa file</u>	<u>epa file</u>
d type	e type
3201 SRMNO	3201 SRMNO
0625 feet	0625 feet
100 ips	100 ips
006667 ftpi	010000 ftpi
006667 sample	010000 sample
w rww_raw	w rww_raw
2 trackno.	2 trackno.
0006 minimum	0006 minimum
0021 maximum	0021 maximum
00.075 increment	00.075 increment
0200 size	0200 size
0.95 It&Irfactor	0.95 It&Irfactor
01.5 Imratio	01.5 Imratio
c current/voltage	c current/voltage
0000 drop	0000 drop
1000 wdr	1000 wdr
0010 DVM1res	0010 DVM1res
9 range	9 range
0100 skip	0100 skip
1000 dly1	1000 dly1
0100 dly2	0100 dly2

0.9990 pnf	0.9990 pnf
0.88 peakpov	0.77 peakpov

4.4.2 Current Source File

The current source file is a table that is used to check the write current. The first column is Id, the desired write current. The values in this column are determined by the parameters file entries for minimum and maximum write current, and the incremental current. With some types of media, the second column will be the source current setting needed to obtain the desired write current. However, with this type of media (SRM 3201), this column is left identical with the first column. The third column is Ia, the actual write head current, as measured by the digital voltmeter. It is provided as data in the event that there should ever be a question regarding the precision of the current source.

4.4.3 Correction Factors File

The use of the correction factors file is a software option for SRM 3201 when calibrating Secondary Standard Reference tapes (see sec. 2.1.). It is intended to permit automatic correction for gain drift in the system. However, the gain stability is much better than the random errors inherent in tape testing on production drives and it tends to add noise rather than correct the very stable system gain. Therefore, it will probably not be used.

The correction factors file is generated when a working tape is run and compared against the data in the "working true" saturation table, obtained when the same working tape was run earlier. The correction file factors contain a table of the differences for both the signal amplitude voltage, and for the amplitude units. Unlike the saturation table files, this file does not have header information and does not have column headings. (It is a temporary file used only for making the secondary corrected saturation tables on that particular day and is not retained.) The first column is Id, the desired write current; the second column is Ia, the actual write current measured; the third column is CFm, the voltage correction factor; and the fourth column is CFa, the amplitude units correction factor. A typical file might look like this:

5.0000	4.9723	0.0001	0.0070
5.1000	5.0682	0.0001	0.0068
...	...	...	...

4.5 Test Result File Naming Conventions

The files for saturation, overwrite, resolution, and peak shift data are named abbbcccc.def where:

```
a is the tape manufacturer
bbb is the tape number
cccc is the pass number
d is the tape type (e.g., d for SRM 3201 low density)
e is the tape class (e.g., Master True) where:
  Test Tape        = 0
  Primary Original = 1
  Master Original  = 2
  Master True      = 3
  Working True     = 4
  Sec. Corrected   = 7
f is the tape test where:
  sat curve = s
  other data = o (resolution, overwrite and peak shift)
  rise data  = r.
```

4.6 Saturation File

The saturation files have a format like that shown in the following example. The column headings are Id, desired write current; Ia, actual (measured) write current; Vm (signal amplitude); and AUs (amplitude units, which are Vm normalized by the Master True peak signal amplitude of 40 AUs)

```
a0211013.e4s filename
a0410000.e3s mtfilename
021690 monthdayyear
dsg operator
002 headnumber
  0.686 Ap_for_test_tape
  9.825 Ip_for_test_tape
  0.651 At_for_test_tape
  8.775 It_for_test_tape
  8.850 Ir_for_master_true
 13.275 Im_for_master_true
  0.602 Am_for_test_tape_at_master_true's_Im
    Id      Ia      Vm     AUs
  6.0000  5.9751  0.3133 18.2180
  6.0750  6.0267  0.3168 18.4184
  6.1500  6.0752  0.3416 19.8583
    ...     ...     ...    ...
```

4.7 Other Parameters File

The "other" files containing overwrite, resolution, and peak shift data, have the following format:

```
a0211016.e4o filename
a0410000.e3o mtfilename
a0211014.e4s satfilename
021690 monthdayyear
dsg operator
002 headnumber
13.2750 Im_for_master_true
 8.7000 It_for_test_tape
```

```
  8.8500 Ir_for_master_true
  0.9831 It_to_Ir
  0.0343 overwrite_for_test_tape
  0.0351 overwrite_for_master_true
  0.9775 overwrite_test_to_master
  0.5931 resol_for_test_tape
  0.5955 resol_for_master_true
  0.9959 resol_test_to_master
  0.6770 f1_volts
  0.0232 f1_residual_volts
  0.0000 f2_volts
  1.0177 f3_volts
  0.6036 f4_volts
 19.2874 peakshift_for_test_tape
 19.6900 peakshift_for_master_tape
 -0.4026 peakshift_test_minus_master
```

4.8 Test Results Logging Procedure

Data from each run is kept in an automated log. The following information is written to a temporary file which will later be imported to a Lotus 1-2-3 spreadsheet:

<u>All Tests</u>

- tape number
- pass number
- file name for test results
- date of test
- head
- operators initials

<u>Sat Test</u>

- Master Standard Reference Tape's File Data
- Peak Signal Amplitude
- Peak Current
- Typical Field
- Typical Current
- Standard Measurement Current
- Signal Amplitude at Standard Measurement Current
- Comments on the test

<u>Rise Test</u>

- Peak Signal Amplitude
- Peak Current
- Percentage of Tilt
- Comments on Run

<u>Overwrite, Resolution, and Peak shift</u>

- Standard Reference Tape's File Data
- Standard Measurement Current
- Typical Current
- Standard Reference Current
- Ratio of Typical Current to Standard Reference Current
- Overwrite value of tape under test

- Overwrite value of Master Standard Reference Tape
- Ratio of test tape's and master tape's overwrite value
- Resolution value of tape under test
- Resolution value of Master Standard reference Tape
- Ratio of test tape's and master tape's resolution value
- F1 value
- F1 residue value
- F2 value
- F3 value
- F4 value
- Percentage of peak shift for test tape
- Percentage of peak shift for master tape
- Difference between master tape's and tape under test's percentage of peak shift

5. PROCEDURE FOR THE USE OF AN SRM 3201 TAPE

The Secondary Standard Reference tapes are sold to industry to use for calibrating tertiary tapes for daily use. Following is a list of steps to follow to use SRM 3201. (This procedure is adapted from the procedure described in ISO/IEC JTC 1/SC 11 N 1 014 Rev. for use with open reel 0.5 inch SRM tapes.)

5.1 Stabilization of the Test System

Switch on the test system and allow a minimum of 1 hour for the temperature of the components to stabilize so that the amplifier gains will remain stable during the following operations.

The test system shall remain switched on until all operations have been completed.

5.2 Procedure for the Calibration of the Test System

To minimize the use of the SRM tape and the risk of damage to it, test the system for correct operation using a tape other than the SRM tape.

Bulk erase and load the SRM tape and make one forward and one reverse pass at normal speed to re-tension the tape.
Note: An SRM tape should never be wound at high speed.

Make a complete forward read-while-write pass with the SRM tape and plot the saturation curve, that is, the curve of average signal amplitude versus write current (see fig. 10).

Writing shall commence at 31 m (100 ft) after the BOT (beginning of tape). Note: Partial passes shall never be made with an SRM tape.

Rewind the SRM tape at normal speed.

Determine the maximum average signal amplitude from the saturation curve.

Determine I1, the minimum write current required to give an average signal amplitude equal to 95 percent of the maximum average signal amplitude. I1 is the current required to produce on the test system the typical field for the particular SRM tape (see fig. 10).

Multiply I1 by the current calibration factor, Cc, provided with the SRM tape, to obtain I2. Cc is ratio of the write current required on the NIST system to produce the reference field to the write current required on the NIST system to produce the SRM tape's typical field. (See data at top of fig. 1.)

I2 is the write current required to produce on the test system the reference field; it is the standard reference current. The reference field is the typical field of the Master Standard Reference tape.

Multiply I2 by 1.5 (the factor specified in X3.197-199X) to obtain I3, the measurement current for the user's test system.

Determine the average signal amplitude A1 produced by the SRM tape at the write current I3.

Multiply A1 by the amplitude correction factor Ca, provided with the SRM tape, to obtain A2. Ca is the ratio of the standard reference amplitude to the average signal amplitude of the SRM tape at the standard measurement current on the NIST system. (See data at top of fig. 1.)

A2 is the standard reference amplitude on the user's test system.

The test system may now be calibrated for overwrite, resolution and peak shift using write current I3 and the relationships printed in the right hand column of the box at the top of the saturation curve chart (see fig. 10).

5.3 Procedure for Calibrating a Tertiary Tape

Bulk erase and load the tertiary tape and make one forward and one reverse pass at normal speed to re-tension the tape. Note: since tapes tend gave a significant rise in the signal amplitude with usage, additional forward and reverse passes shall be made until the rise in signal amplitude per pass is less than 0.05 percent. (Typically, 100 to 200 passes from BOT to EOT to BOT should suffice.)

Make a complete forward read-while-write pass with the tertiary tape, ignoring the first 31 m (100 ft) after BOT, and plot the saturation curve.

Rewind the tertiary tape a normal speed.

Determine the maximum average signal amplitude.

Determine It1, the minimum write current required to give an average signal amplitude equal to 95 percent of the maximum average signal amplitude.

The current calibration factor for the tertiary tape relative to the Master Standard Reference tape shall be calculated from the ratio:

$$Ctc = \frac{I2}{It1} .$$

Determine At1, the average signal amplitude at the write current I3.

The amplitude calibration factor for the tertiary tape relative to the Master Standard Reference tape shall be calculated from the ratio:

$$Cta = \frac{SRA}{At1} .$$

Overwrite, resolution and peak shift may now be measured for the tertiary tape using the write current I3.

Note: it may be desirable to rerun the SRM tape at the conclusion of the above operations to verify the stability of the test system. However, the SRM tape should not be run more than necessary.

We wish to acknowledge Steven Boone, Michael O'Brien, James Chu, and the Digital Equipment Corporation (Digital) for providing information on how to make modifications to the TK70 tape drive, developing a TD70-B controller (TD50-B with custom firmware), donating a tester assembly (housing) with power supplies and fans, and various technical advice; Paul Jahnke with the Minnesota Mining and Manufacturing Company (3M) for technical advice; Matt Jacobs as a member of Technical Committee X3B5 for obtaining instrument donations for this SRM and for SRM 3202; Stanford Research Systems for the donation of an SR620 time interval counter needed for the

peak shift measurements; and those member companies of Technical Committee X3B5 (Digital Equipment Corporation, Minnesota Mining and Manufacturing Company, Storage Technology Corporation, Laser Magnetic Storage, Carlisle Memory and Pericomp Corporation) who contributed financially via the Computer Business Equipment Manufacturers Association for the development of new SRMs.

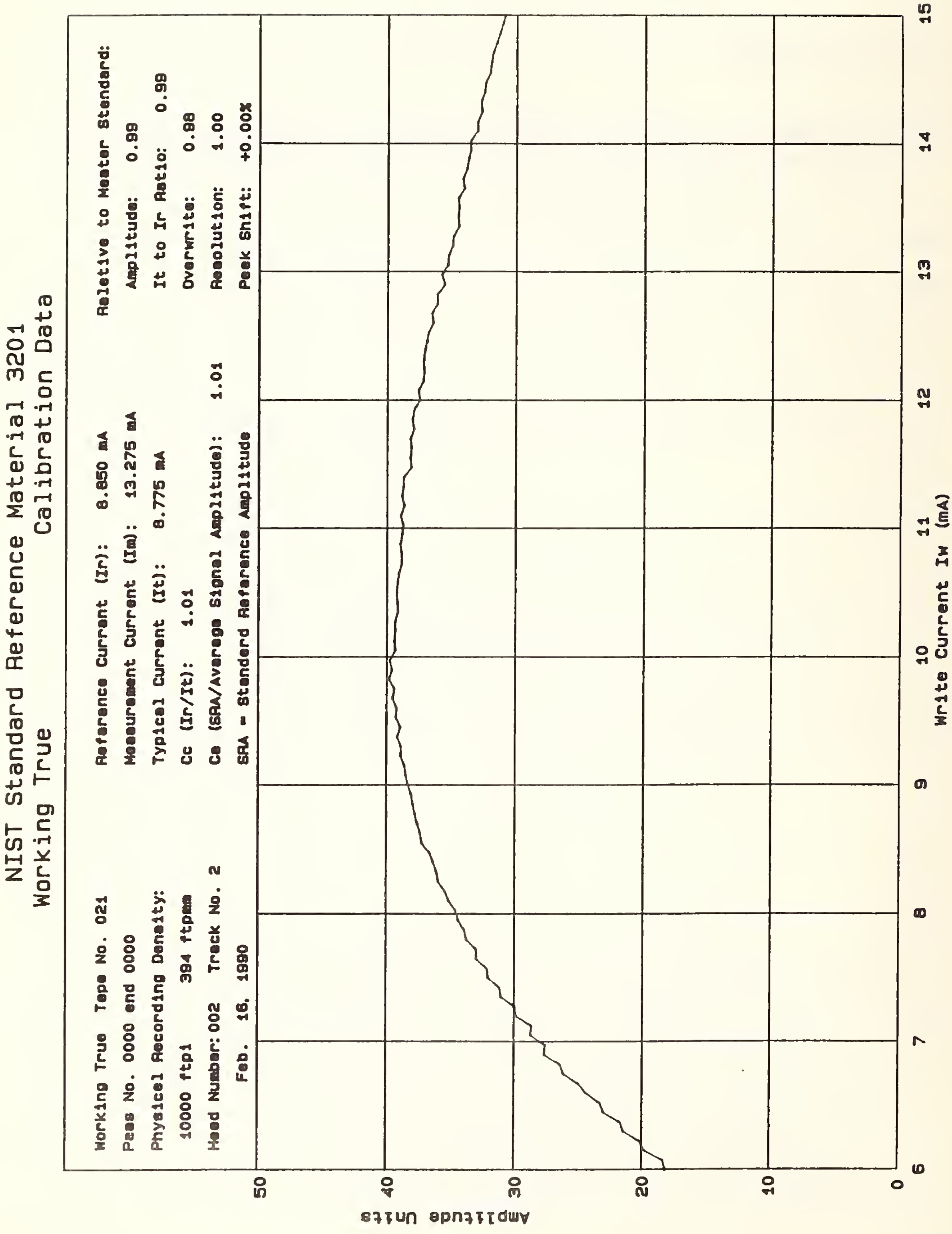
6. REFERENCES

[1] Podio, F., "A New Computer-Based Self-Correcting Calibration System for Computer Storage Media Standard Reference Material," Computers and Standards: The International Journal, Vol. 4, No. 4 (1985).

[2] American National Standard (ANSI) X3.181-1990.

[3] American National Standard (ANSI) X3.197-199x.

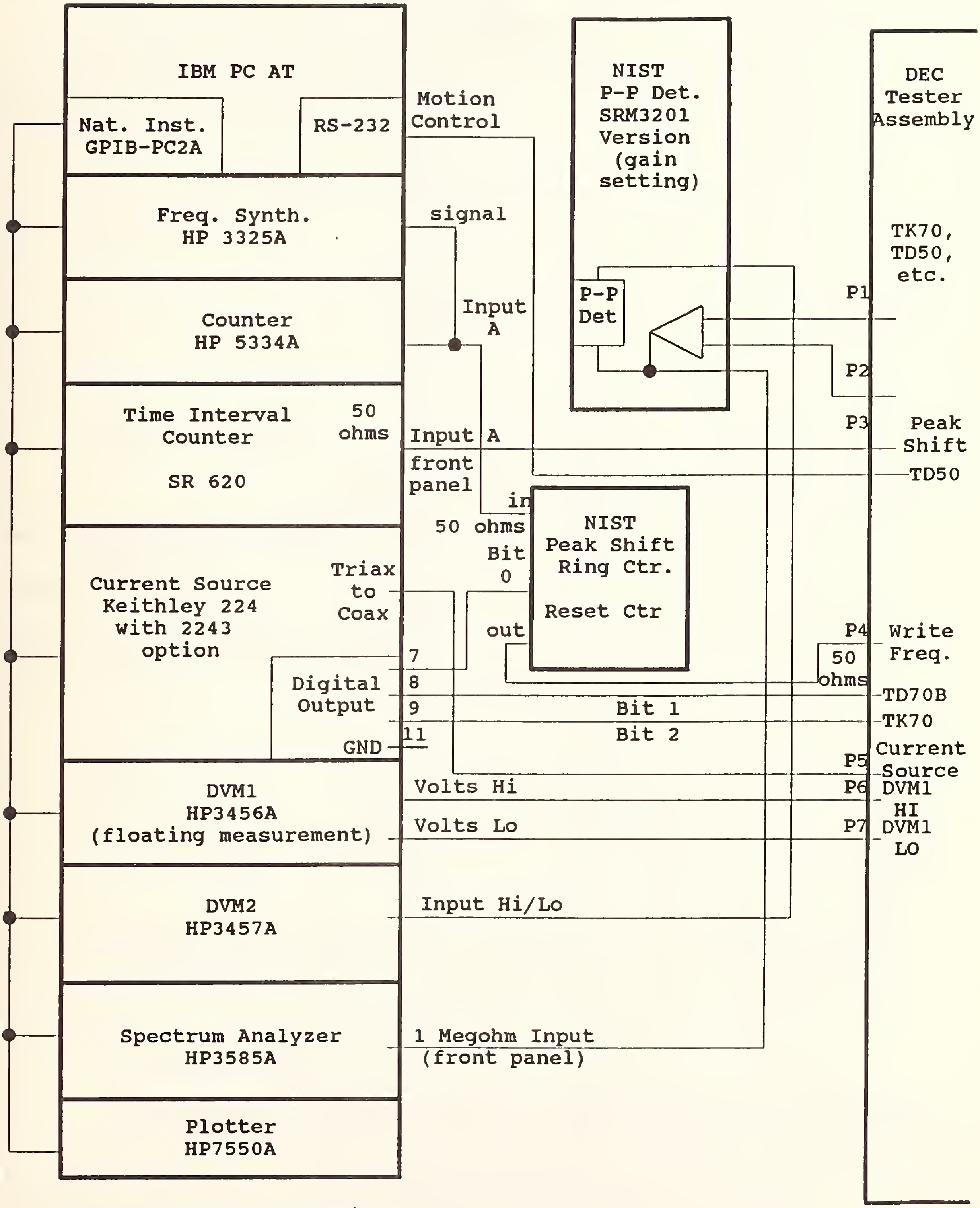
Figure 1



NIST Standard Reference Material 3201
Working True
Calibration Data
Working True Tape No. 021
Pass No. 0000 and 0000
Physical Recording Density:
10000 ftpi 394 ftpmm
Head Number: 002 Track No. 2
Feb. 16, 1990
Reference Current (Ir): 8.850 mA
Measurement Current (Im): 13.275 mA
Typical Current (It): 8.775 mA
Cc (Ir/It): 1.01
Ca (SRA/Average Signal Amplitude): 1.01
SRA = Standard Reference Amplitude
Relative to Master Standard:
Amplitude: 0.99
It to Ir Ratio: 0.99
Overwrite: 0.98
Resolution: 1.00
Peak Shift: +0.00%
Amplitude Units
0
10
20
30
40
50
6
7
8
9
10
11
12
13
14
15
Write Current Iw (mA)

Figure 2

System 3 Setup for SRM 3201



All rear panel connections

Figure 3

DEC Tester Assembly
for
SRM 3201

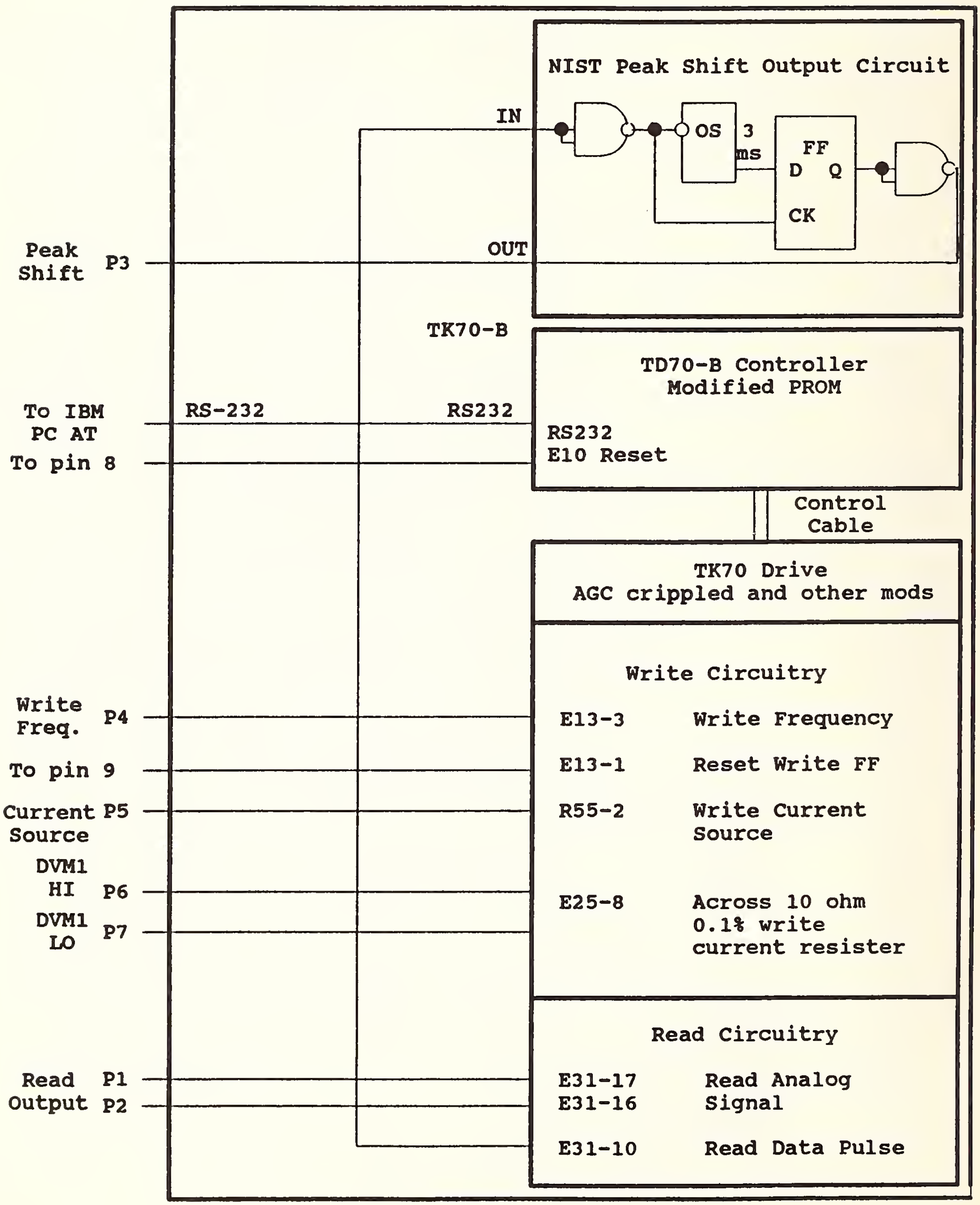
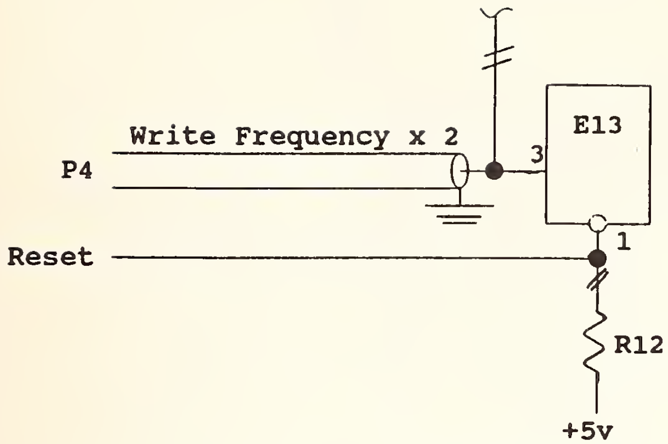
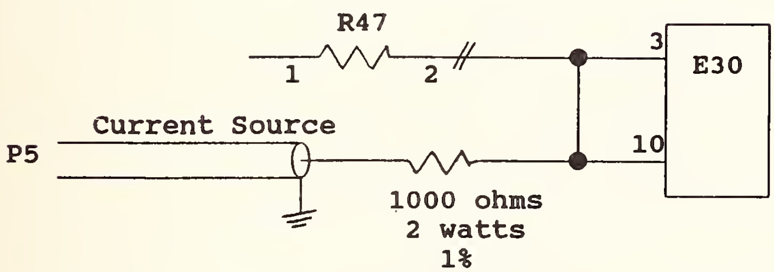


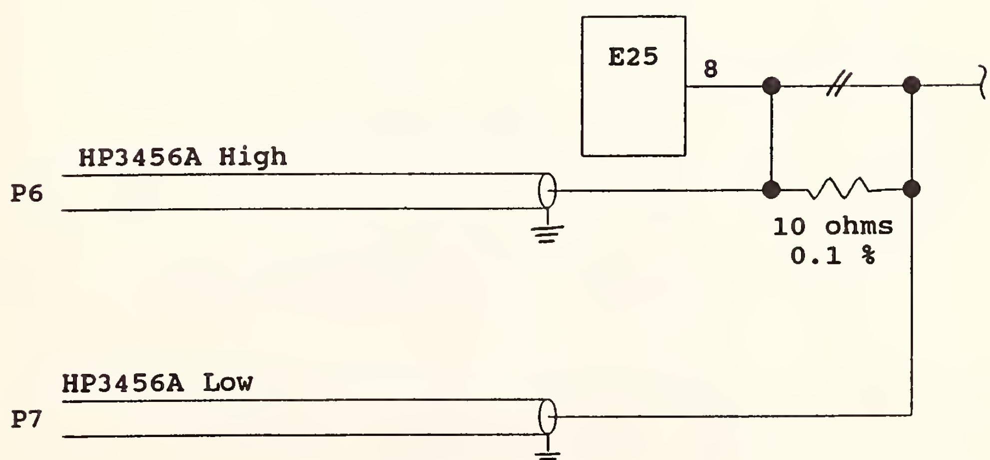
Figure 4



Write Frequency Input



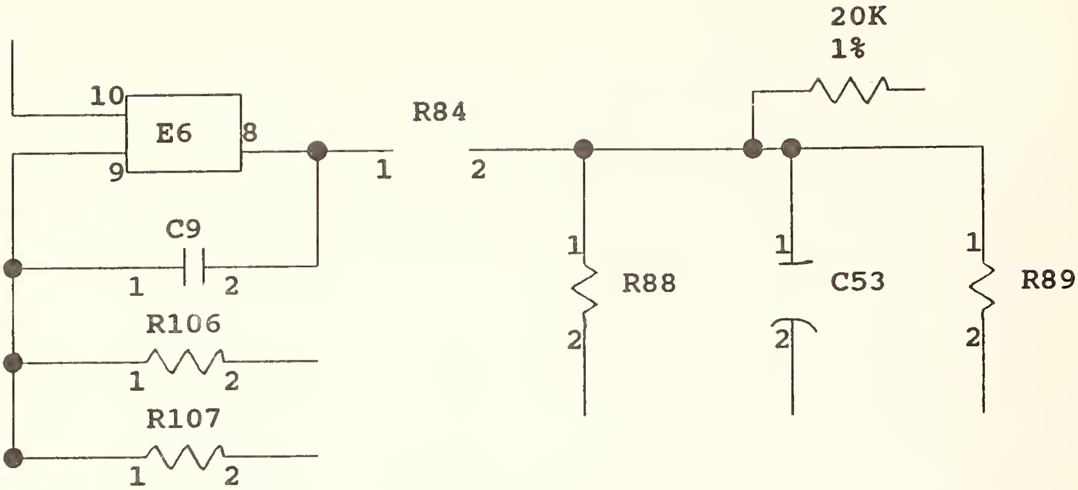
Current Source Input



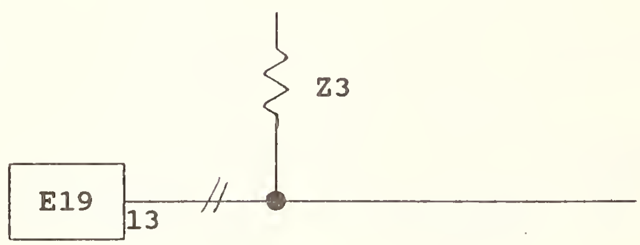
Write Current Measurement

Tape Drive Modifications

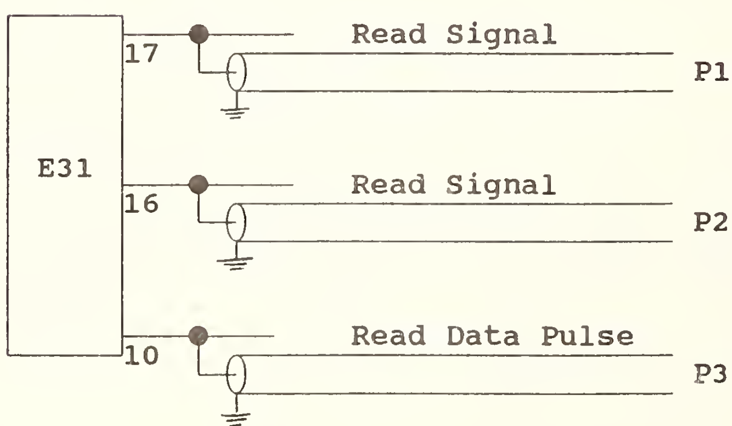
Figure 5



CRIPPLE AGC



Read Amplitude High Disable



Signal Amplitude and Peak Shift
Data Output

Figure 6

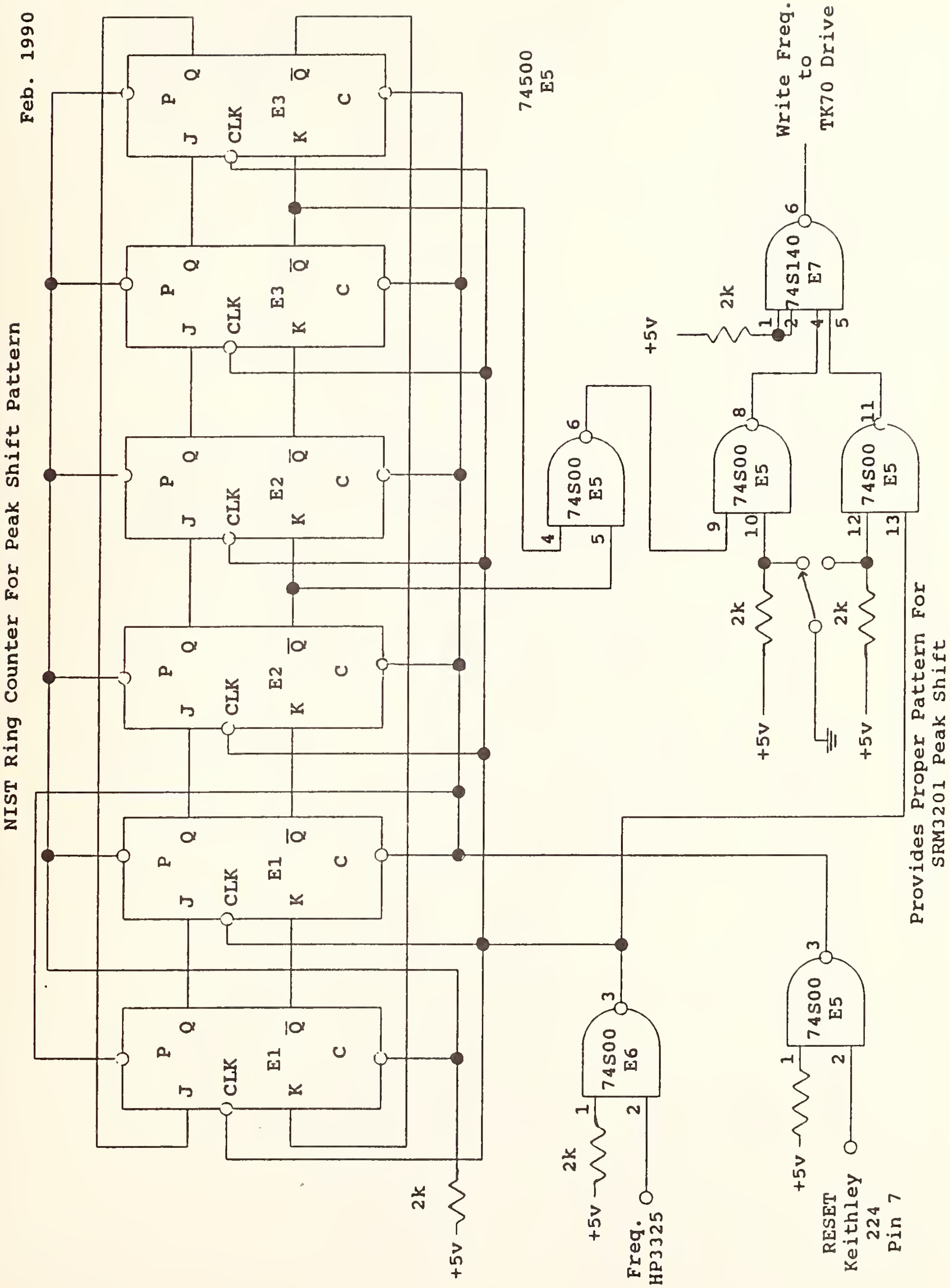

NIST Ring Counter For Peak Shift Pattern
Feb. 1990
E1
E1
E2
E2
E3
E3
74S00
E5
74S00
E6
74S140
E7
Write Freq.
to
TK70 Drive
Provides Proper Pattern For
SRM3201 Peak Shift
Freq.
HP3325
RESET
Keithley
224
Pin 7
2k
+5v

Figure 7

Peak Shift Output Circuit

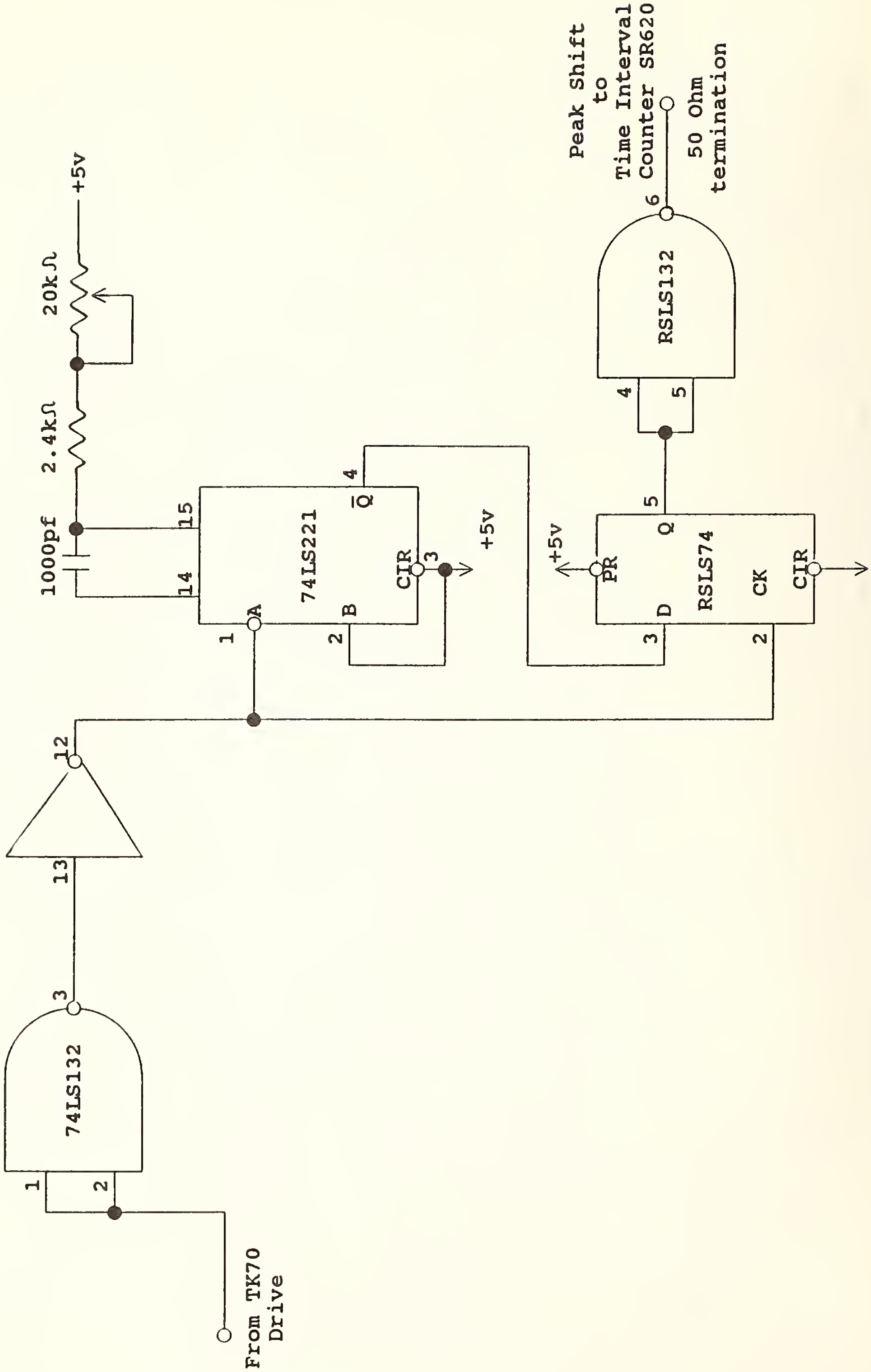
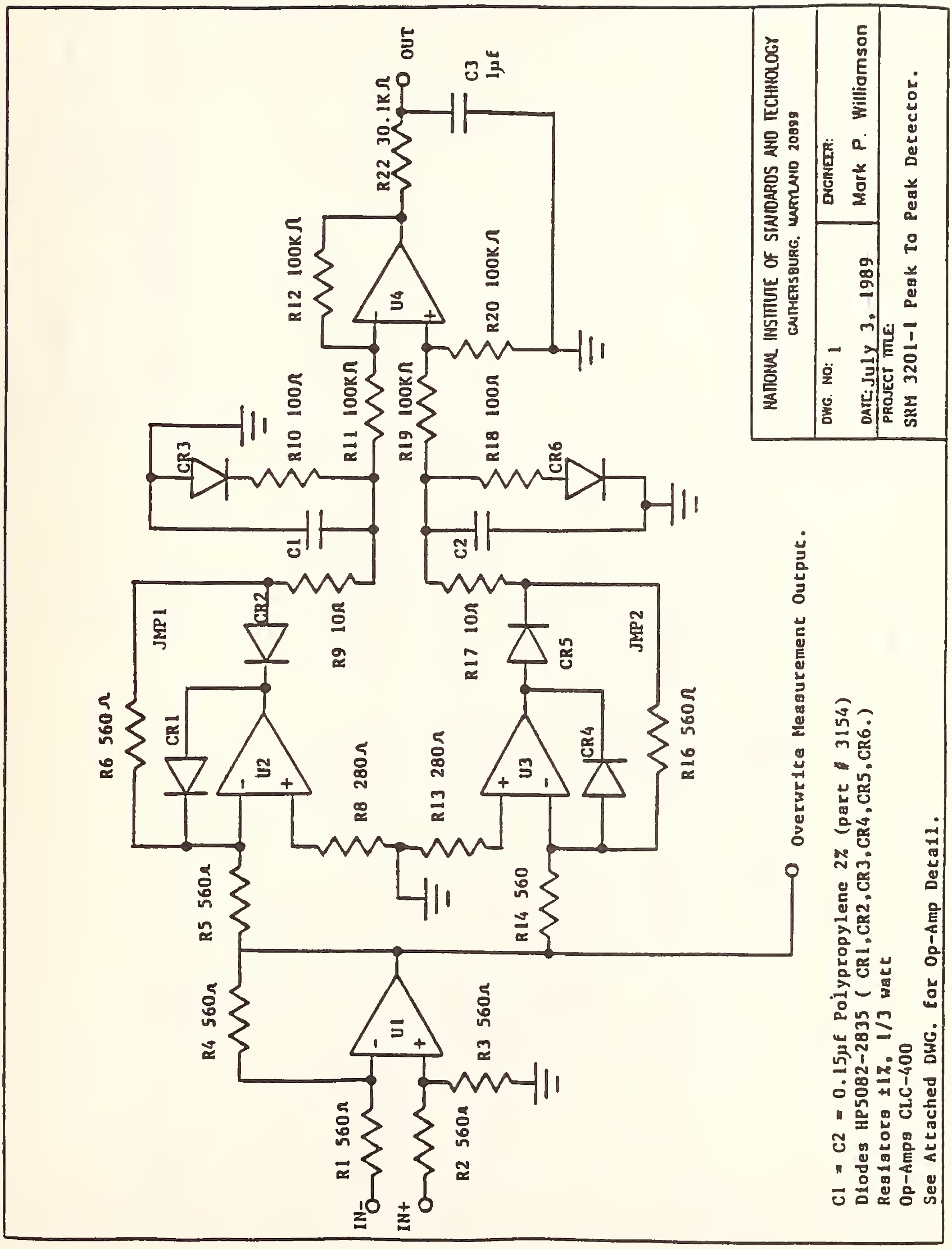


Figure 8



NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY
GAITHERSBURG, MARYLAND 20899
DWG. NO: 1
DATE: July 3, 1989
ENGINEER:
Mark P. Williamson
PROJECT TITLE:
SRM 3201-1 Peak To Peak Detector.
OUT
C3 1µf
R22 30.1KΩ
R12 100KΩ
U4
R20 100KΩ
R11 100KΩ
R19 100KΩ
R10 100Ω
R18 100Ω
CR3
CR6
C1
C2
CR2
CR5
R9 10Ω
R17 10Ω
JMP1
JMP2
R6 560Ω
CR1
U2
R8 280Ω
R13 280Ω
U3
CR4
R16 560Ω
R5 560Ω
R14 560
R4 560Ω
U1
R3 560Ω
R1 560Ω
R2 560Ω
IN-
IN+
Overwrite Measurement Output.
C1 = C2 = 0.15µf Polypropylene 2% (part # 3154)
Diodes HP5082-2835 (CR1,CR2,CR3,CR4,CR5,CR6.)
Resistors ±1%, 1/3 watt
Op-Amps CLC-400
See Attached DWG. for Op-Amp Detail.

Figure 9

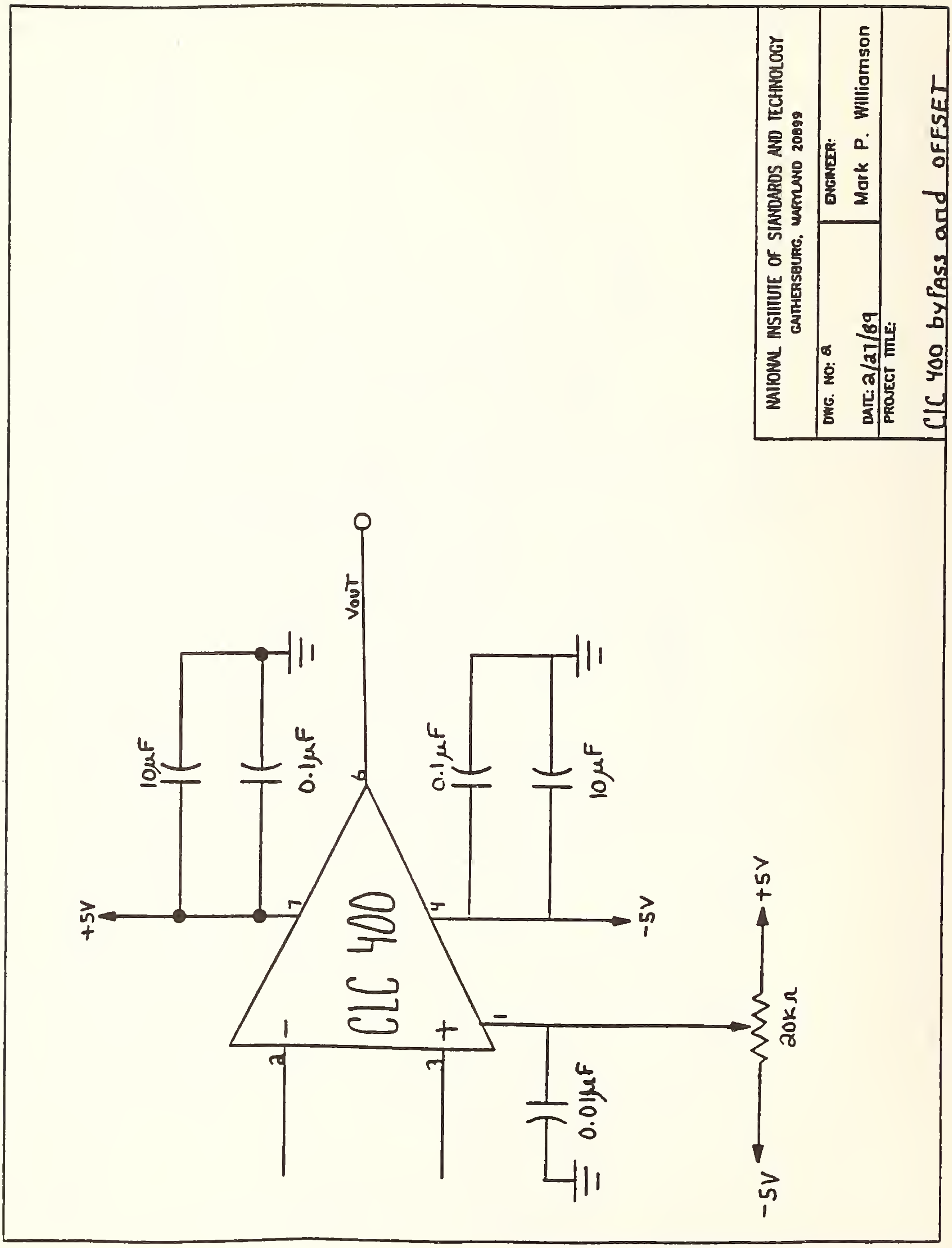
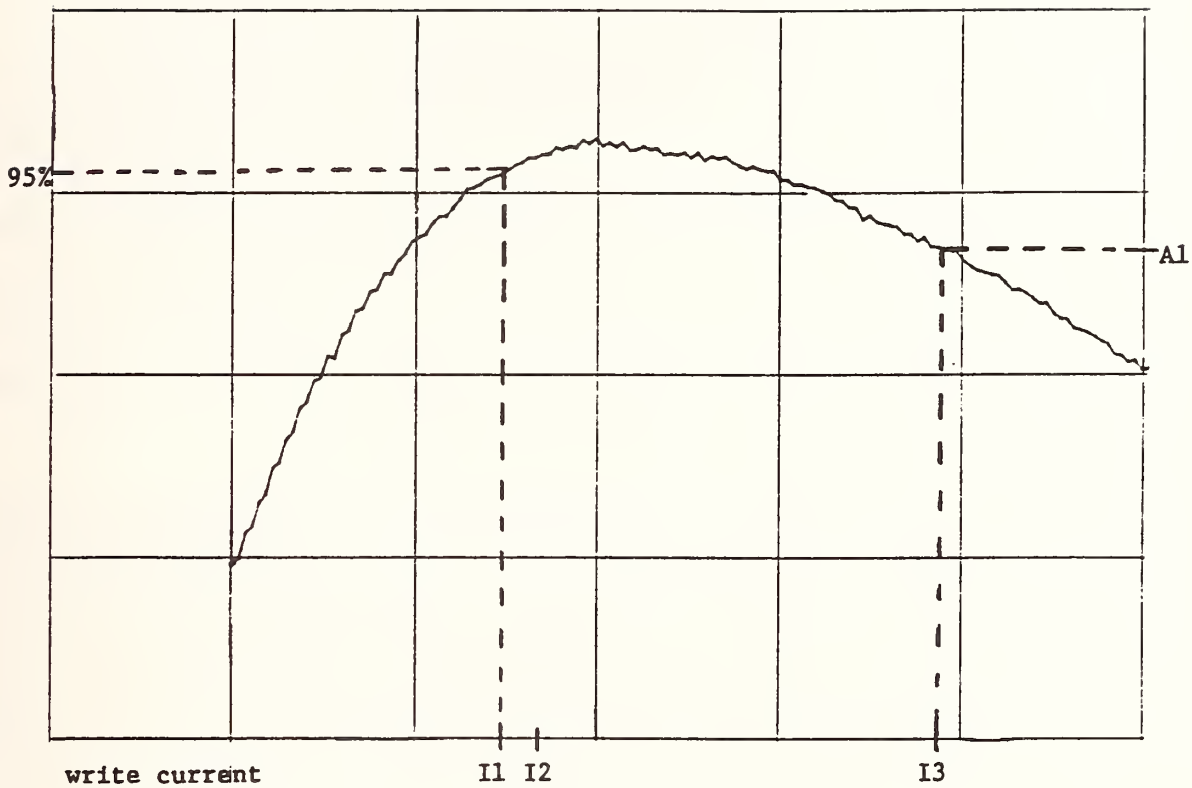

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY
GAITHERSBURG, MARYLAND 20899
DWG. NO: 8
DATE: 2/27/89
ENGINEER:
Mark P. Williamson
PROJECT TITLE:
CLC 400 bypass and OFFSET
+5V
10µF
0.1µF
VOUT
0.1µF
10µF
CLC 400
-5V
+5V
20kΩ
0.01µF
-5V

Figure 10



Saturation Curve on User's Test System

NIST-114A
(REV. 3-89)

U.S. DEPARTMENT OF COMMERCE
NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY

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11. ABSTRACT (A 200-WORD OR LESS FACTUAL SUMMARY OF MOST SIGNIFICANT INFORMATION. IF DOCUMENT INCLUDES A SIGNIFICANT BIBLIOGRAPHY OR LITERATURE SURVEY, MENTION IT HERE.)

This publication describes the test system design and operation for the calibration of the NIST secondary standard reference tapes SRM 3201 for 0.5 inch (12.65mm) 22 and 48 track serial serpentine magnetic tape cartridges. The importance of producing a Standard Reference Material for this magnetic tape cartridge is to promote the ability to interchange data both within and among various computer installations. Reliable interchange is assured when the media is designed and manufactured on the basis of a comparison to a known and accepted standard reference media.

12. KEY WORDS (6 TO 12 ENTRIES; ALPHABETICAL ORDER; CAPITALIZE ONLY PROPER NAMES; AND SEPARATE KEY WORDS BY SEMICOLONS)

digital magnetic tape; Master Standard Reference tape; overwrite; peak shift; Secondary Standard Reference; signal amplitude; Standard Reference Material

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